Fuzzy Logic Approach for Impact Source Identification in Ceramic Plates

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Abstract

A great deal of interest has been shown in the literature in the development of new Non-Destructive Techniques (NDT). In particular, there is increasing interest in detecting, evaluating and locating cracks as well as the source of the impact causing these cracks. *Fuzzy logic* was shown to be useful in *crack detection, and severity of crack in materials. In this paper* Fuzzy logic has been used in NDT applications *for identification of source of impact on the ceramic plates. Through the experimental techniques* described *in this paper we show that fuzzy logic can be used successfully for this purpose. The proposed* methodology *has been implemented as a Mamdani Fuzzy Inference System (FIS) using the Fuzzy Logic Toolbox in MATLAB.*

Introduction

There has been some significant work published on non-destructive techniques for detecting [4], locating and evaluating cracks [1,2] in materials. A related problem, determining the source of impact, has not received much consideration. This paper makes an effort to focus attention on the identification of material of source of impact. The large number of variables involved makes the task of impact source determination very unwieldy. Some of the variables include, the material being impacted, the impacting material, size of the impacting object, striking force etc. An approach for impact source identification is described in this paper.

A ceramic plate is divided to 16 sections, to obtain and analyze results precisely. When the ceramic plate is hit on any section by different impact sources, it will generate waveforms with different behavior. An approach of analyzing the output waveform to identify the impact source is proposed. FIS is used to identify Impact Source. When the surface of the plate is hit, it will generate a waveform. Using a Data Acquisition System (DAS), an Excel data sheet is obtained from the waveforms. The data sheet incorporates important information that is extracted from the waveforms like RMS values, Mean, Median, Mode, Peak Value and Fast Fourier Transform(FFT) value. These outputs act as the inputs to the Fuzzy Inference Model. The procedure to get the output by considering data values directly from the text file having inputs such as RMS values, Mean, Median, Mode, Peak Value and Fast Fourier Transforms is discussed.

Test System Description and Methodology

The authors address the problem of determining the source (type of material hitting the plate) of impact in a laboratory environment. The scope of this experiment is described by the following constraints:

- The impact was simulated through an electric impact hammer.
- The device hit the impacted surface with a force, adjusted to be within a relatively small range, from a fixed distance.

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14. ABSTRACT
A great deal of interest has been shown in the literature in the development of new Non-Destructive Techniques (NDT). In particular, there is increasing interest in detecting, evaluating and locating cracks as well as the source of the impact causing these cracks. Fuzzy logic was shown to be useful in crack detection, and severity of crack in materials. In this paper Fuzzy logic has been used in NDT applications for identification of source of impact on the ceramic plates. Through the experimental techniques described in this paper we show that fuzzy logic can be used successfully for this purpose. The proposed methodology has been implemented as a Mamdani Fuzzy Inference System (FIS) using the Fuzzy Logic Toolbox in MATLAB.

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- The only variable was the material used for impacting head. The impacting materials used were Steel and a durable plastic Delrin®.

The hypothesis is that different impacting materials will generate different impact acoustic waves, but the impact waves will not differ significantly if the impacting source is the same. The variables like RMS, mean, median, mode, peak value and FFT value of the generated impact waves may be used as parameters to differentiate the impact waves.

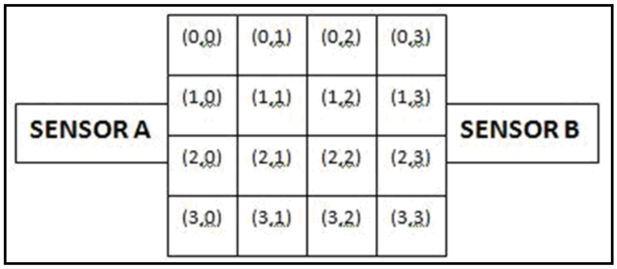


Fig. 1: Test System Circuit: Two Sensor Arrangement of the ceramic plate (courtesy of [1])

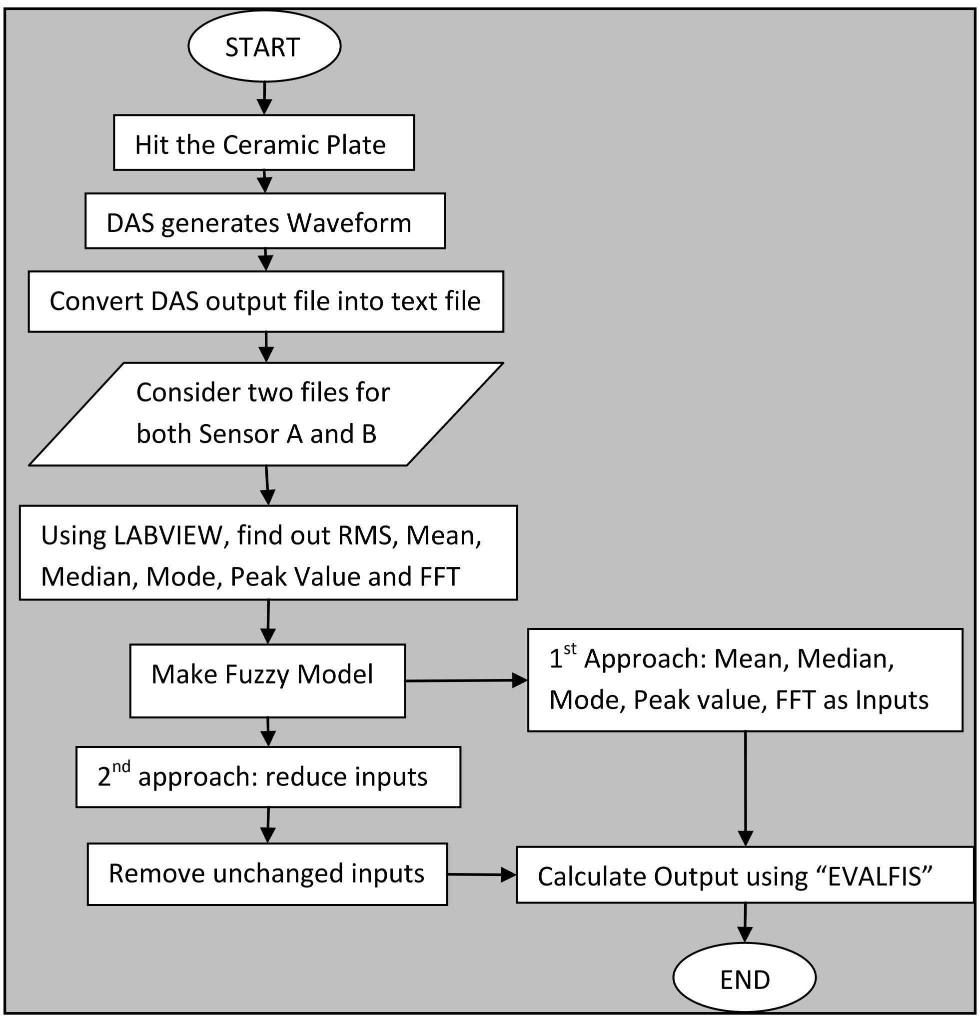


Fig. 2: Flowchart for Impact Source identification

Fig. 1 shows the two sensor arrangement of a ceramic plate. The two piezoelectric sensors are arranged on opposite sides of the ceramic plate. The Plate is divided into 16 sections indexed (0, 0) to (3, 3). The output waveform contains two waveforms one from sensor A and one from sensor B for all the sections. We get two different values for the same parameter i.e., one from Sensor A and another from Sensor B. Different impact sources are used to create impact onto different sections in ceramic plate. : The vibration patterns recorded by the sensors will change based on the location of impact. Thus different sections will generate different data files.

The method used for the impact source identification as shown in Fig. 2 consists of the following steps:

1. Consider two sensor arrangements for impact source identification.

2. Hit the surface with defined source. (Steel and Delrin® sources are used.)

3. DAS acquires waveforms generated by the impact. (Two waveforms from sensor A and sensor B, respectively.)

4. Save these waveforms from sensor A and sensor B in two data files.

5. Obtain RMS value, Mean, Median, Mode, Peak value and FFT value from output files generated by DAS. (Apply MATLAB or LABVIEW commands.)

6. Define fuzzy model using Mamdani type FIS by considering absolute values of the parameters.

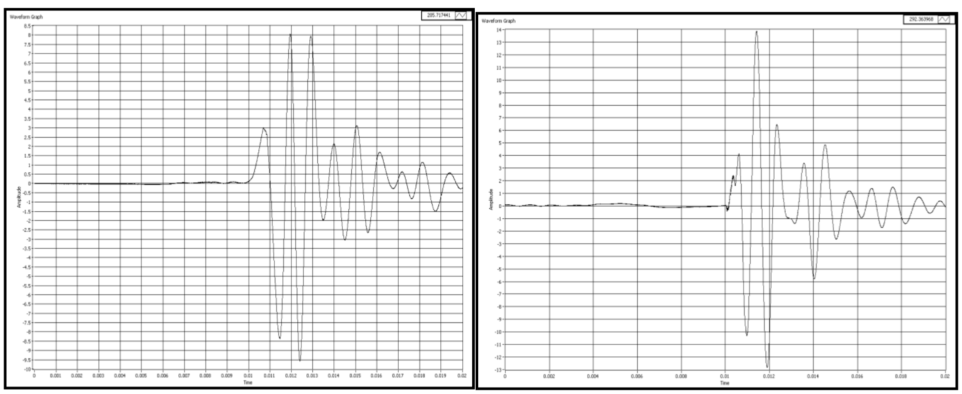


Fig.3 Sample waveforms obtained after creating Impact from Delrin® on left and Steel on right on section(0,2)

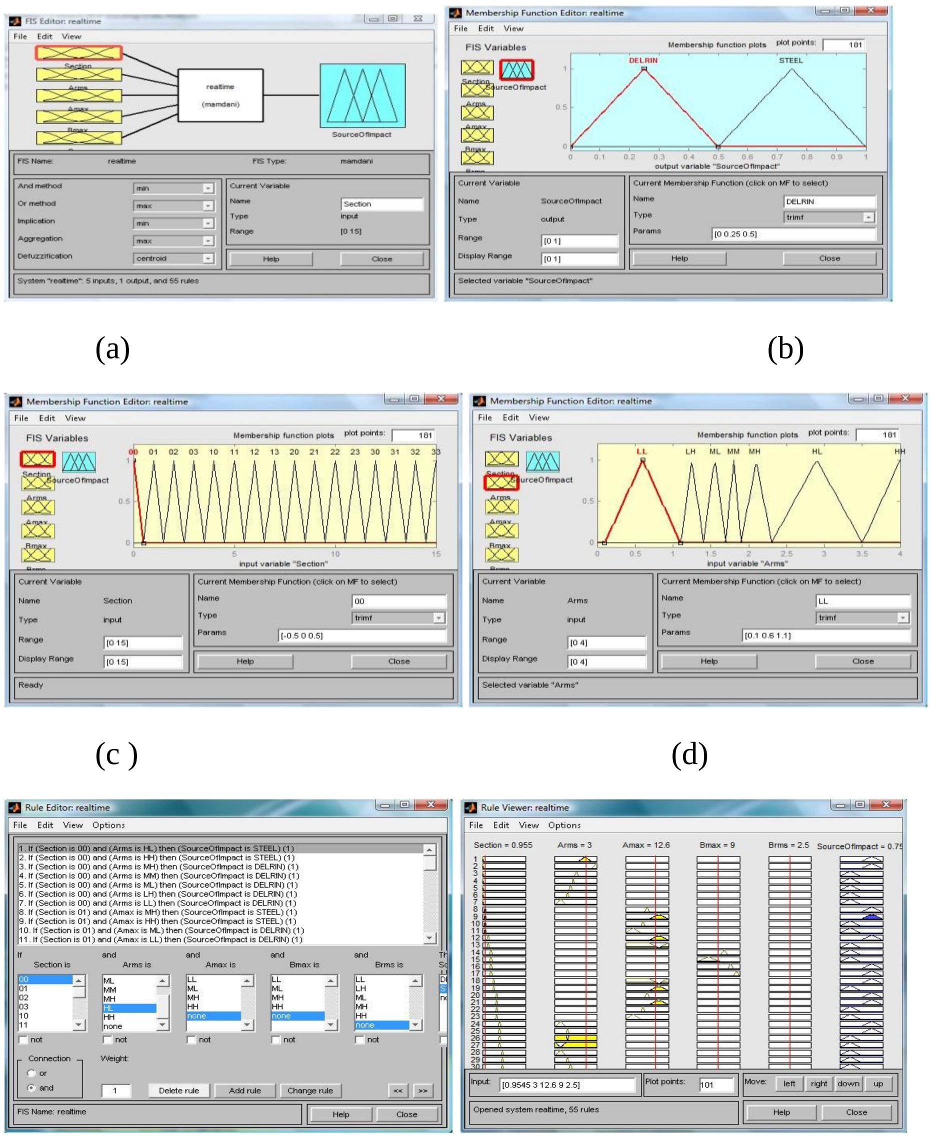
Fig. 3 shows different sample waveforms obtained after creating impact with Steel and Delrin® on a section of the plate. Note that these waveforms are from only one of the two sensors. Data extracted from these waveforms can be seen in Table 1 in the Appendix**.**

Table 2: Range Defined for Inputs

	LL	LH	ML	MM	MH	HL	HH
Arms	0.1 – 1.1	1.1 - 1.4	1.4 – 1.7	1.7 – 1.9	1.9 – 2.3	2.3 – 3.5	3.5 - 4
Amax	0 - 6.5	--	6.5 – 8	--	8 – 10	--	10 - 18
Brms	0 – 1.5	1.5 – 2.4	2.4 – 2.9	--	2.9 – 3.3	--	3.3 - 5
Bmax	0 – 10	--	10 – 13	--	13 – 15.4	--	15.4 - 18

Fuzzy Impact Source Identification Approach on Real Time System

In a real time environment, to detect the source of impact, we use the following parameters: RMS value, Peak value, Median, Mode and FFT value. There are two sensors present on either side of the plate i.e., A and B as described. The values obtained from the DAS are in the form of waveforms obtained from sensor A and Sensor B for same parameter. So there are eleven inputs used in the FIS, corresponding to the above defined five input parameters for each of the two sensors. All the parameters are used to develop a fuzzy model [3,4,5] in order to implement it in a real time environment.



(a) (b)

(c) (d)

(e) (f)

Fig. 4 Fuzzy Inference System: (a) five Inputs, (b) Output membership function, (c, d) Input membership function, (e) Rule Editor, (f) Rule Viewer

The FIS consists of 11 input parameters (1 location index, 5 inputs from sensor A, and 5 inputs from Sensor B) and one output, which the source of impact. On analyzing this approach, some of the inputs were found to be superfluous; therefore, we used five inputs rather than ten. The parameters that were ultimately used are the Location Index, Arms, Amax, Brms and Bmax for they are proved to be the most effective in determining the source

of impact. The ranges that were taken into consideration for the FIS formation are described in Table 2. Range sets for these Input parameters are determined after analyzing data obtained and the membership functions were decided accordingly. As outputs in Fuzzy Logic are always measured between 0 and 1, we observed that a value of around 0.25 corresponds to Delrin® and 0.75 to Steel in the FIS developed. Fig. 4 shows the FIS developed using Fuzzy Logic Toolbox in MATLAB for five Inputs.

Conclusion

The Fuzzy Logic approach was investigated and shown to be a candidate for impact source identification. A MATLAB implementation for the identification of material of impact source was written. The experiment was performed on limited data and only two sources of impact though had a high correlation to training data. Future work will involve more data and identification of more number of impact sources to validate the proposed technique. The FIS identifies whether the source of impact is Steel or Delrin®. It is hoped that the approach suggested here will lead to more reliable techniques for impact source identification on ceramic plates.

References:

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Appendix

Table 1: Data File for captured Impact Waveforms.

INDEX	A-RMS	A-MEAN	A-MEDIAN	A-MODE	A-MAX	A-FFT	B-RMS	B-MEAN	B-MEDIAN	B-MODE	B-MAX	B-FFT	OUTPUT
(0,0)	2.853457	-0.14467	-0.20569	0.089661	17.63706	0.550063	2.232264	0.070128	0.0966	-0.23224	11.12996	-0.5005	Steel
(0,0)	2.12684	-0.04041	0.402387	-1.36973	10.24457	0.506629	1.197423	0.035839	-0.15435	-0.11974	5.262808	-0.50915	Delrin®
(0,1)	2.625784	-0.10151	0.098347	0.506629	14.74435	0.506629	2.556979	-0.02271	-0.06782	-0.76011	12.49723	-0.5005	Steel
(0,1)	1.90866	-0.03329	0.358952	0.367639	8.611444	0.506629	2.448746	0.016999	0.243712	0.001411	9.304045	0.50332	Delrin®
(0,2)	2.786107	-0.09544	0.202589	0.402387	16.05606	0.506629	2.995505	-0.05068	0.113908	-17.6866	10.78381	0.537935	Steel
(0,2)	1.854013	-0.03527	0.367639	0.367639	8.029426	0.515315	2.875283	0.035245	0.451399	-0.68223	8.101193	0.50332	Delrin®
(0,3)	2.703809	-0.04608	-0.0059	0.689052	15.73465	-0.52711	3.831043	0.381775	0.131215	-17.6866	17.74997	0.520628	Steel
(0,3)	2.110172	-0.01396	-0.44024	-1.1873	12.96355	-0.50104	3.070854	0.11412	0.312941	-17.6866	9.529039	0.511974	Delrin®
(1,0)	2.005689	-0.09951	0.072287	-0.55317	8.342152	-0.50104	2.187488	-0.01156	-0.11109	-0.73415	9.892491	0.537935	Steel
(1,0)	2.874385	-0.02179	0.133095	0.020166	9.888408	0.506629	1.603892	0.012873	-0.26685	-0.82934	8.300226	-0.5005	Delrin®
(1,1)	1.676259	-0.04012	-0.04064	0.3937	8.724373	-0.50104	1.573216	-0.0493	-0.02455	0.511974	6.34451	-0.5005	Steel
(1,1)	2.009339	-0.06173	0.028853	0.202589	6.830643	-0.50973	1.532659	-0.05534	-0.11109	-0.48319	8.568488	-0.50915	Delrin®
(1,2)	1.364033	-0.22585	-0.05802	-0.15357	4.832671	0.654305	2.122266	-0.10742	-0.06782	0.840811	9.174241	-0.5005	Steel
(1,2)	1.409268	0.04077	-0.10145	-0.62266	5.866405	-0.50973	2.107622	0.023921	0.105254	0.235058	8.040618	-0.5005	Delrin®
(1,3)	1.84302	-0.02824	-0.07539	-0.07539	10.27063	0.506629	2.782996	-0.12632	-0.11109	-0.46588	10.46363	-0.5005	Steel
(1,3)	1.506111	0.009663	-0.10145	-0.10145	7.681953	-0.50973	3.466485	0.095551	0.312941	0.581203	9.399235	0.50332	Delrin®
(2,0)	3.196053	-0.11055	-0.04064	-0.30993	17.02899	-0.50104	3.197639	0.013569	0.018718	-0.76876	17.08364	0.511974	Steel
(2,0)	4.061507	0.308466	0.219963	-17.7097	15.52616	0.506629	2.745315	-0.04166	-0.36204	1.559061	13.04241	-0.5005	Delrin®
(2,1)	2.037907	0.004193	0.167842	-0.9267	8.038113	-0.51842	1.761954	-0.08027	-0.11974	-0.12839	9.191549	0.650432	Steel
(2,1)	2.866071	0.050799	0.107034	-0.67478	11.7387	-0.50104	1.23982	-0.00197	-0.0332	-0.18032	5.574338	-0.5005	Delrin®
(2,2)	1.214743	0.009582	0.03754	0.054913	5.258326	0.515315	2.696384	-0.07744	-0.13705	0.442745	14.13276	-0.5005	Steel
(2,2)	1.034875	0.03807	-0.02327	-0.08408	4.198533	-0.50973	1.96891	-0.00735	0.027372	-0.57838	7.045452	-0.50915	Delrin®
(2,3)	1.993676	-0.05754	-0.04933	-0.64003	10.10558	0.506629	3.392241	-0.01939	-0.13705	-17.6866	17.74997	-0.5005	Steel
(2,3)	1.569075	-0.00172	0.011479	-0.90933	6.995693	0.515315	4.025684	0.23467	0.200444	-17.6866	15.24908	0.50332	Delrin®
(3,0)	2.042179	0.020811	0.298145	0.58481	6.517917	0.515315	1.195682	-0.09605	-0.09378	-0.10243	5.74741	-0.51781	Steel
(3,0)	2.442594	0.067239	0.193903	-0.18832	11.0177	0.506629	1.271079	-0.0109	-0.0159	-0.21493	3.739772	0.50332	Delrin®
(3,1)	2.328408	0.026579	0.107034	-0.01458	8.316091	0.532689	2.34575	-0.12826	-0.04186	-0.89857	9.130973	-0.51781	Steel
(3,1)	2.777088	0.028069	0.454508	0.619557	9.905782	0.506629	2.584544	0.009786	0.209097	-1.2101	9.918452	0.511974	Delrin®
(3,2)	1.685406	-0.00442	0.159155	0.341579	6.109636	0.515315	2.451635	-0.14123	-0.11974	-1.16683	10.37709	0.555242	Steel
(3,2)	2.226247	-0.03299	-0.01458	0.03754	7.212864	0.506629	3.210857	-0.07702	-0.1457	-17.6866	9.269431	0.50332	Delrin®
(3,3)	1.549162	-0.02246	0.0636	0.402387	7.74276	-0.53579	2.293778	-0.12116	-0.1457	-0.17166	11.104	0.581203	Steel
(3,3)	2.083231	-0.10249	-0.0059	-0.43155	5.82297	0.515315	2.387345	0.088187	0.200444	-1.25336	6.950263	0.50332	Delrin®